

PIM Test Power Level

Introduction:

The industry recognized specification for Passive Intermodulation (PIM) testing is IEC 62037. This specification was first released in 1999 and updated in 2012. This specification defines the technical requirements for PIM test equipment as well as provides test procedures for measuring RF components such as connectors, cable assemblies, antennas and filters. The current version of the specification only addresses factory PIM testing. A working group within the IEC will address the unique challenges of field PIM testing with portable test equipment in a future release of the specification.

In order to promote measurement consistency, IEC 62037 currently recommends that components used in mobile communications systems be tested using 2x 20 Watt (43 dBm) test tones. This recommendation has served the wireless industry well through the development and deployment of 2G and 3G systems. With the more stringent requirements of 4G and 5G systems, demand for higher linearity (lower PIM) construction is needed. With this need, it is time to reassess the historical test power level recommended by IEC 62037 and determine if 40 Watt (46 dBm) test power might better serve modern mobile communications networks.

Background:

Passive Intermodulation (PIM) testing is intended to measure the linearity of a system. This is done by injecting two test signals into the device under test while measuring the magnitude of intermodulation products generated by the device. If the magnitude of the intermodulation product is low, the system is linear. If the magnitude of the intermodulation product is high, the system is non-linear. The third order intermodulation product (IM3) frequency is typically measured to evaluate linearity. IM3 levels lower than -150 dBc are typically considered "good" for RF components when tested with 2x 20 Watt (43 dBm) test tones.

It is possible to perform linearity tests over a wide range of test powers. Figure 1 shows linearity measurements (PIM tests) conducted on four different objects with the test power varied between 2.5W (34 dBm) and 40W (46 dBm). The objects include two RF cables, a coupler and the PIM analyzer itself. The PIM analyzer measurements were made with a low PIM termination attached to the output port of the instrument. This test measures the "self-generated" or "residual" PIM of the analyzer at each test power. The other measurements were made with one port of the device under test (DUT) connected to the PIM analyzer and the second port of the DUT connected to a low PIM termination.

PIM vs Power - Various objects

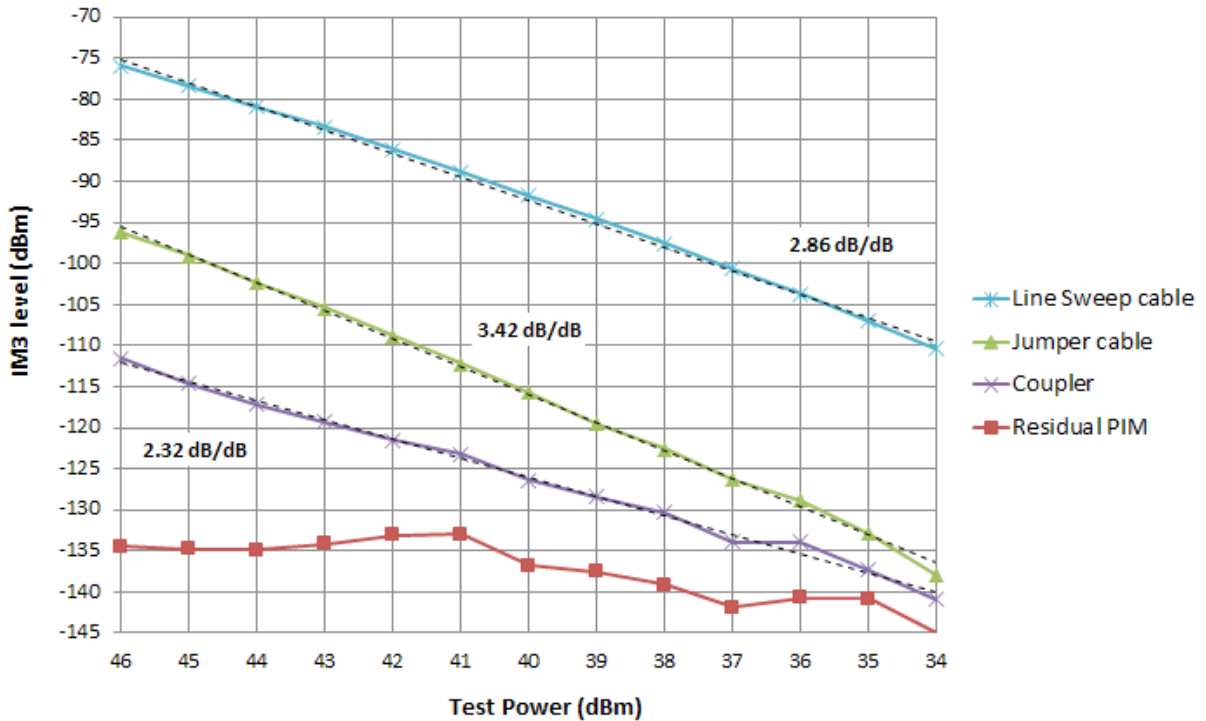


Figure 1: PIM vs. Test Power for a variety of objects.

Looking at the data in figure 1, it is interesting to note that the change in PIM level vs. power for each device is nearly constant over the range of powers tested. For every 1 dB change in test power, the PIM level changes by a fixed number of dB. For third intermodulation products, the theoretical “slope” of the PIM vs. power curve is 3.0 dB / dB. Actual values vary, as indicated by the data shown in figure 1.

Using the previously stated criteria of -150 dBc (-107 dBm) at 20W (43 dBm) test power as a “line in the sand” to judge the linearity of the objects tested, we can conclude the following:

Device	IM3 level @ 20W	Linearity
Line Sweep Test Cable	-83 dBm / -126 dBc	Fail - very poor linearity
Jumper Cable	-105 dBm / -148 dBc	Fail - but just barely
Coupler	-119 dBm / -162 dBc	Pass - very good linearity

Table 1: Linearity judgement for devices tested in Figure 1

Equivalent PIM tests:

If we want to judge the linearity of a device using a different test power we can do so by calculating an equivalent pass fail level using the theoretical 3 dB/dB PIM slope. As an example, if you have a linearity specification of 166 dBc (-123 dBm) @ 20W (43 dBm) and want to know what an equivalent test specification level would be at 5W (37 dBm), it could be calculated as follows:

- Change in power = 43 dBm - 37 dBm = -6 dB
- Expected change in PIM = -6 dB x 3.0 dB/dB = -18 dB
- Equivalent test specification = -123 dBm - 18 dBm = -141 dBm (-178 dBc)

Similarly, if you wanted to calculate an equivalent test specification at 40W (46 dBm), it could be calculated as follows:

- Change in power = 46 dBm - 43 dBm = +3 dB
- Expected change in PIM = +3 dB x 3.0 dB/dB = +9 dB
- Equivalent test specification = -123 dBm + 9 dB = -114 dBm (-160 dBc)

Figure 2 shows an example from a manufacturer’s datasheet showing two different PIM specifications for a 4.3-10 series RF connector when tested at different test power levels. As demonstrated in calculations above, the 20W specification of -166 dBc is equivalent to the 40W specification of -160 dBc. Test accuracy may be higher when this device is tested at 40W, as will be discussed in the next section, but the linearity assured by these two test specifications is equivalent.

Intermodulation • 2 × 20 W • 2 × 40 W	IEC 62037-3	-166 dBc (0.4 to 4 GHz) -160 dBc (0.4 to 4 GHz)
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Figure 2: PIM test specification from manufacturer’s data sheet.

PIM test accuracy:

If an equivalent test level can be determined for any power level, why does the IEC specification recommend 20W? Why not test at a lower power level to make the test safer and to reduce the size / cost of the test equipment? The answer to this question is measurement accuracy. In addition to recommending 20W test power, the IEC specification also states that the residual PIM of the test instrument must be 10 dB lower than the PIM level you are attempting to measure. Figure 3 shows possible measurement error as a function of the difference between the PIM signal level and residual PIM level of the instrument. With a 10 dB difference, the minimum required by the IEC specification, a measurement error of +2 dB / -3 dB is possible. With a difference of only 5 dB, the measurement error increases to +4 dB / -7dB. As the signal level increases above the residual PIM of the instrument, the measurement error is reduced. At 20 dB difference, the measurement error reduces to less than 1 dB.

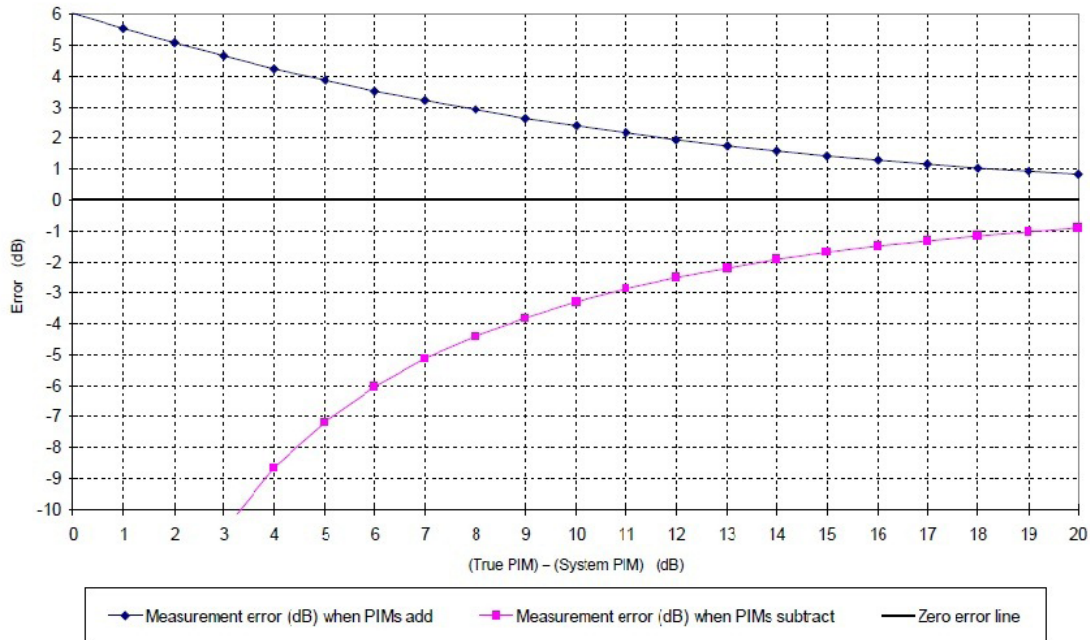


Figure 3: Measurement error curve from IEC 62037.

As discussed in the previous section, for every 1 dB increase in test power the IM3 generated by a device increases by approximately 3 dB. This provides a practical way to boost the magnitude of the PIM signal you are measuring and potentially increase measurement accuracy. Looking again at the data in figure 1, we see the following differences between residual PIM and measured PIM for the three objects tested:

Item	40W (46 dBm)	20W (43 dBm)	5W (37 dBm)
Line Sweep Test cable	58.5 dB	50.7 dB	41.3 dB
Jumper Cable	38.3 dB	28.7 dB	15.6 dB
Coupler	22.9 dB	14.8 dB	8.0 dB

Table 2: Difference between measured PIM and residual PIM for items tested in Figure 1

In this example, the PIM analyzer is able to meet the “10 dB above residual PIM” requirement for all devices at all test powers except for the Coupler at 5W test power. To measure this very low PIM device accurately the test power would need to be increased to at least 40 dBm (10W). It is interesting to note that measurement accuracy increased for all devices tested as the test power was increased. This is true due to the extremely low residual PIM of the test analyzer combined with the fact that the residual PIM did not increase significantly as the test power is increased. This may not be the case for all test instruments and is a factor that should be taken into account when considering changes in test power.

More stringent testing:

A second benefit of increasing test power is that it potentially provides the ability to more stringently test the linearity of the devices. Going back to our 4.3-10 connector example, the PIM level specified at 20W testing is -166 dBc (-123 dBm). In order to accurately verify this specification per IEC 62037, the residual PIM of the test analyzer must be better than -133 dBm. If the residual PIM of the analyzer could also be maintained below -133 dBm at 40W test power, the same -123 dBm PIM level could be applied. A level of -123 dBm @ 46 dBm test power is -169 dBc, a 9 dB more stringent test than is currently specified. A warning must be stated here that a residual PIM level of -133 dBm at 40W test power represents the current state of the art in PIM test equipment technology. Levels like this are possible today in lab test environments but may not be practical to achieve in field test environments.

PIM issue missed by 20 Watt test:

In the examples discussed so far, the change in PIM vs. test power (PIM slope) has been constant over a wide range of test powers. But what about cases where the PIM slope is not constant? In those cases, the linearity of a device is changing as the power changes and choice of test power can have a significant impact on the result. Such a case was recently observed at a cell site containing a combination of internal and external PIM sources. When the PIM of this site was measured over a range of power levels, a rapid increase in PIM was observed at higher power levels.

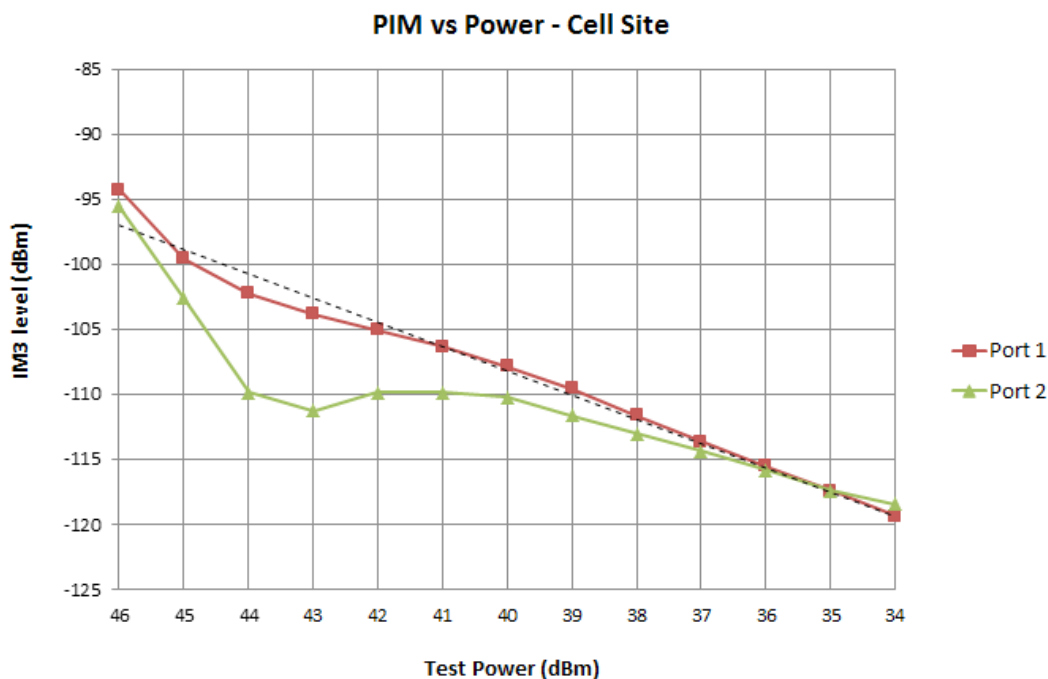
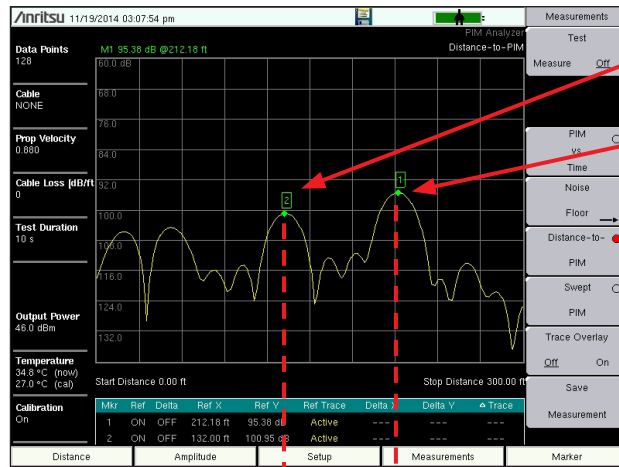


Figure 4: PIM vs. Test power measured at a cell site.

Distance-to-PIM measurements on this system helped reveal the reason for the non-constant PIM vs. power results. At low power levels, a PIM source inside the feed system was dominant. This internal PIM source established the PIM slope for power levels below 25W (44 dBm). At power levels above 25W a second PIM source beyond the antenna became dominant. This second PIM source had a “steeper” PIM slope resulting in higher PIM values as the power level increased.

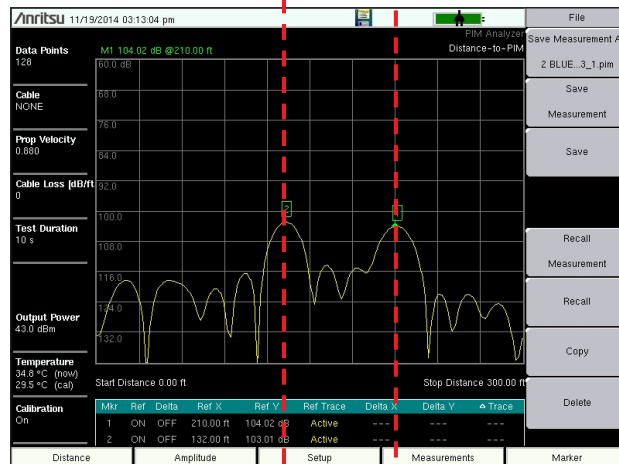
40W test power
External PIM source dominant



PIM source #1
(in feed system)

PIM source #2
(beyond the antenna)

20W test power
Internal & external PIM sources have similar magnitude



10W test power
Internal PIM source dominant

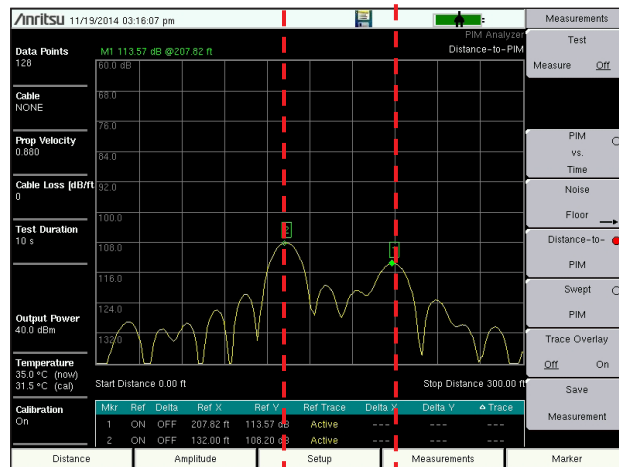


Figure 5: Distance-to-PIM measurements at different test power levels.

In this example, PIM testing either port at 20W test power did not provide a true indication of the PIM level experienced at higher power levels. Testing with 40W test power not only provided a more accurate indication of actual noise levels seen at the site, but also exposed the dominant PIM problem outside the system.

Conclusion:

There is nothing technically wrong with using 20W power levels to PIM test mobile communications systems. Manufacturers and installers have been able to make significant improvements in network performance using 20W PIM test equipment to find and eliminate sources of non-linearity. However, to meet the more stringent demands of 4G and 5G networks even lower PIM levels are required from our wireless infrastructure. As described in this paper, doubling the test power from 20W to 40W has been shown to improve measurement accuracy and to provide a way forward for more stringently testing mobile communications systems and devices.

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